Hydraulics

3rd Year civil

First Term (2009 - 2010)

Chapter ( )

Revision Part (5)
solved examples

The pump having the characteristics given by the following table is to be used I a pipe line system with the following characteristics, two tanks with 40 ft difference in static water surface, f = 0.020 , 8 inch diameter , 1000 ft long , 4 bends each have km = 0.90, one glob valve km = 10, the pipe line is connected to the tanks.

Find,

(i) The operating condition for the pump,

(ii) Input power of the pump

Q (gpm)	0	500	800	1000	1300	1600
H (ft)	124	119	112	104	90	70
Eff. (%)	0	54	64	68	70	67

Sol.:

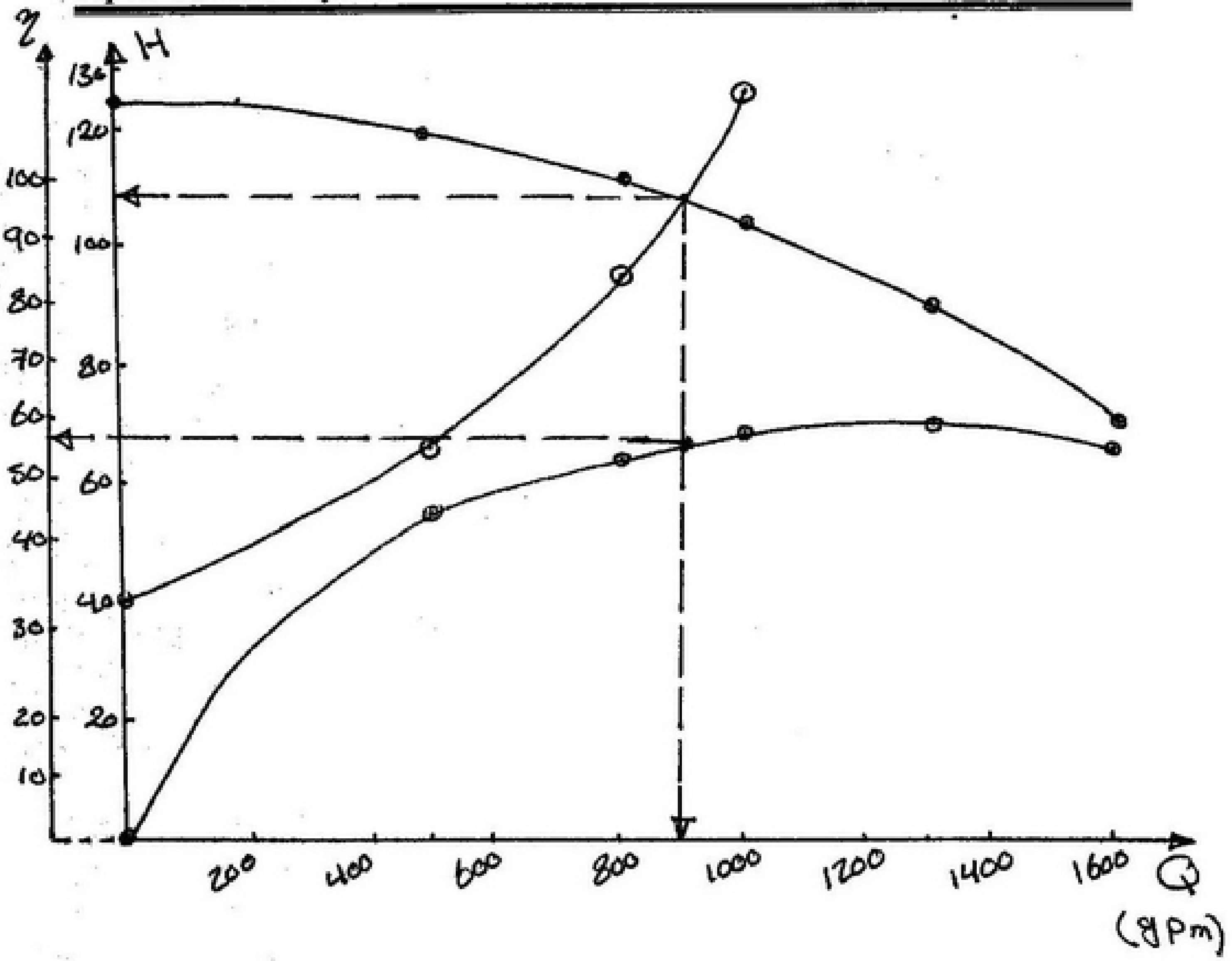
$H_{st.} = 40 \text{ ft.}$, $f = 0.020$

$d = 8 \text{ inch}$, $L = 1000 \text{ ft.}$

$K_m = 4 \times 0.9 + 10 = 13.60$

ملحوظة

$1 \text{ ft}^3/\text{sec.} = 449 \text{ (gpm)}$



$$\because \quad H_P = H_{st.} + H_L$$

$$H_P = 40 + \left[\frac{8 f . L}{g \pi^2 d^5} + K_m\right] Q^2$$

$$H_P = 40 + \left[\frac{8 \times 0.02 \times 1000}{32.2 \times \pi^2 \times \left(\frac{8}{12}\right)^5} + 13.6\right] Q^2$$

ملحوظة للتحويل من (in) إلى (ft) نقسم على (12)

$$\therefore \boxed{H = 40 + 17.42\,Q^2}$$

وللتعويض عن Q في المعادلة نأخذ الأرقام الموجوده في الجدول ونقسمها على (449) قبل التعويض في المعادلة

Q	0	500	800	1000	1300	1600
H	40	61.6	95.3	126.4	186.0	261.2

من نقطة التشغيل

$Q \simeq 900$ gpm #

$H \simeq 110$ ft. #

$\eta \simeq 57\ \%$ #

$$\because \quad H.P = \frac{\gamma \cdot Q \cdot H}{550 \times \eta}$$

$$H.P = \frac{62.4 \times (900/449) \times 110}{550 \times 0.57}$$

$$= 92.7 \quad H.P \quad \#$$

A pressure pipe line of 3.00 km length is to be constructed to convey thr irrigation water against a static head of 31.00 m the minimum required discharge is 280 m^3/hr , while the maximum discharge required 320 m^3/hr, the sum of the minor losses $5(v^2/2g)$, three pumps are available and the characteristics of each pump is tabulated below,

$Q(m^3/hr)$	0	40	80	120	160	200	240	280	320
H (m)	60	58	55	50	45	38	27	17	15
Eff. (%)	0	40	70	88	90	78	65	50	40
N.P.S.H(m)		3	3.20	3.50	4.0	4.20	4.70	5.20	5.50

Two pipe lines are available, the diameter of the first pipe line is 0.30 m while the diameter of the second pipe is 0.40 m the pipe friction factor have a constant value F = 0.020 for both pipe,

Required,

(1) Which pipe size is to be constructed to convey the max. and the min. discharge,

(2) Find the maximum pump height above the water level

Given:

- $L = 3000\,m$, $H_{st.} = 31.0\,m$
- $Q_{min} = 280\ m^3/hr$, $F = 0.02$
- $Q_{max} = 320\ m^3/hr$
- $K_m = \dfrac{5V^2}{2g}$

pipe (1) : $D = 0.30\,m$

pipe (2) : $D = 0.40\,m$

ملحوظة: نظراً لوجود قطرين مختلفين للمواسير سوف يتم عمل منحنيين للتشغيل منحنى لكل ماسورة

<u>For pipe (1):</u>

$$\because H = H_{st} + H_L$$

$$H_L = K_m + K_{friction}$$

$$K_m = \frac{5V^2}{2g} = \frac{5Q^2}{2gA^2} = \frac{5Q^2}{2g(\pi/4 \times D^2)^2}$$

$$= \frac{5Q^2}{2 \times 9.81 \times \frac{\pi^2}{16} \times D^4} = \frac{0.413}{D^4} Q^2$$

$$\therefore H = H_{st} + \left[\frac{8f.L}{\pi^2 . g . D^5} + K_m\right] Q^2$$

$$\therefore H = 31.0 + \left[\frac{8 \times 0.02 \times 3000}{\pi^2 \times 9.81 \times 0.3^5} + \frac{0.413}{0.3^4}\right] Q^2$$

$$H_{pipe(1)} = 31.0 + 2091.2\, Q^2$$

Q	0	40	80	120	160	200	240	280	320
H	31	31.30	32.0	33.2	35.1	37.5	40.3	43.7	47.5

For pipe (2):

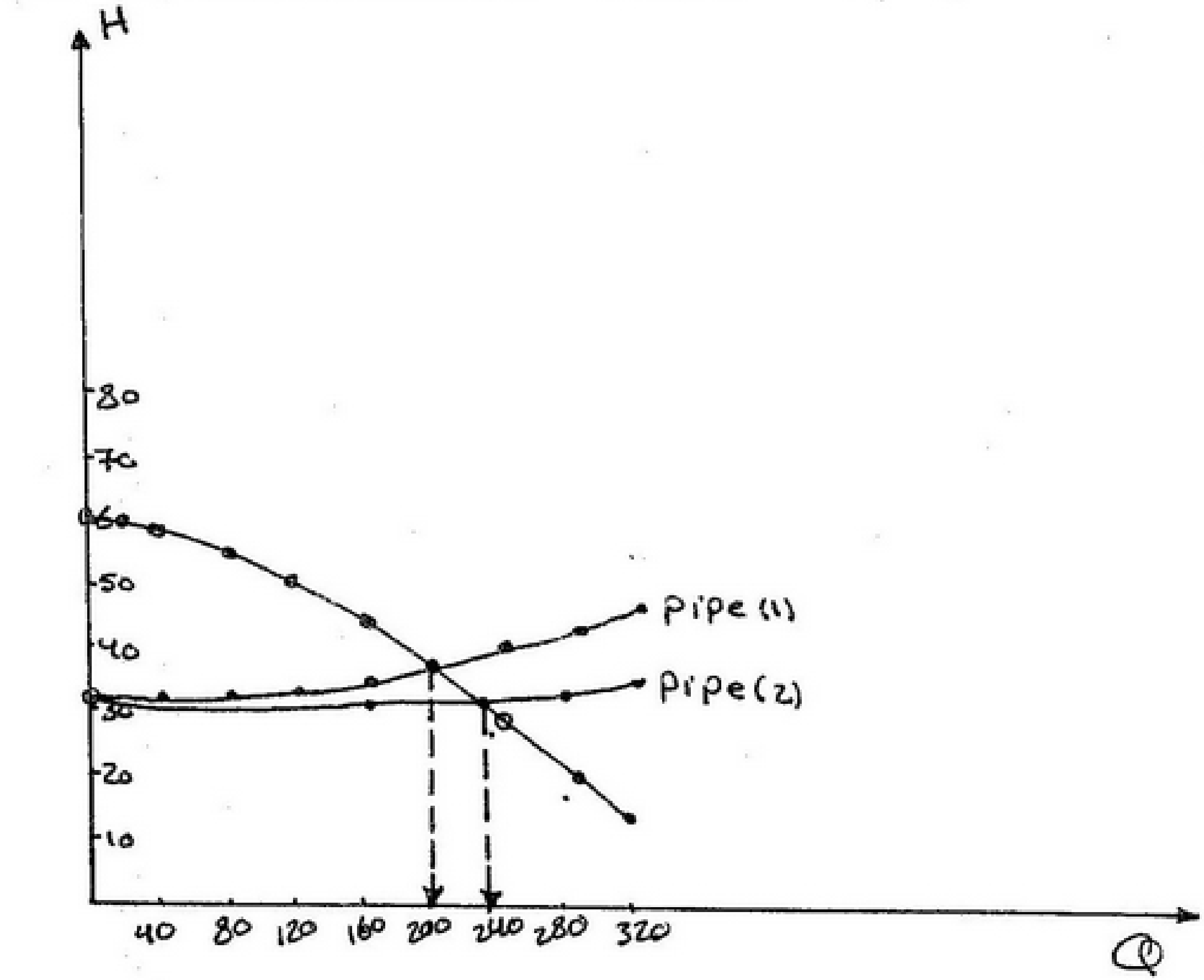
$$\because H = 31 + \left[\frac{8 \times 0.02 \times 3000}{\pi^2 \times 9.81 \times 0.45} + \frac{0.413}{0.4^4} \right] Q^2$$

$$H = 31.0 + 500.30\, Q^2$$

Q	0	40	80	120	160	200	240	280	320
H	31	31.1	31.2	31.6	32.0	32.5	33.2	34.0	35.0

ملحوظة

قبل التعويض عن قيمة Q يتم قسمتها على (3600) للتحويل من (m^3/hr) إلى (m^3/sec.)



* نفضل استخدام خط المواسير قطر 40 cm حيث أن فواقد التشغيل الناتجة منه أقل .

* استخدام مضخة واحدة غير كافٍ لتوصيل التصرف ونفضل زيادة عدد المضخات المستخدمة لنقل التصرف

(1) In a model built on a Froude law of similarity a phenomenon for 20 minutes if the model scale is 1/25, what would be the duration of the phenomenon in the prototype in minutes?

(2) In a 1/60 model of spillway , the discharge was measured 0.15 m3/sec., what would be the corresponding discharge in the prototype

Sol.:-

(1) $\because \quad T_r = \dfrac{T_m}{T_p}$

for Froude similarity $\quad T_r = L_r^{1/2}$

$$\therefore \frac{T_m}{T_p} = L_r^{1/2}$$

$$\frac{20}{T_p} = (1/25)^{1/2}$$

$$\therefore T_p = 100 \text{ min. } \#$$

(2) $\because \quad Q_r = \dfrac{Q_m}{Q_p} = \dfrac{L_r^3}{T_r} = \dfrac{L_r^3}{L_r^{1/2}}$

$$\frac{Q_m}{Q_p} = L_r^{2.5}$$

$$\frac{0.15}{Q_p} = (1/60)^{2.5}$$

$$Q_p = 4182 \quad m^3/s \ \#$$

An ogee spillway of a gravity dam is to be modeled using water, the spillway section is 40 ft height, its crest length is 60 ft, and the maximum discharge 3000 cfs, when the head on the crest of the spillway 5.0 ft, using a scale 1:5 calculate the height of the model, the head on the crest, and the discharge, and the length of the time the model must be operated to check the equivalent of 36 hr of the prototype operation.

Req.:

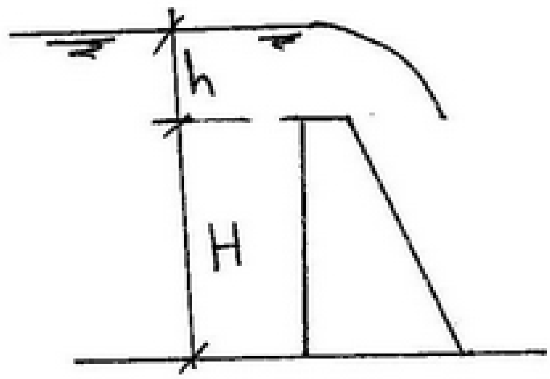
$H_m = ?$, $h_m = ?$

$Q_m = ?$, $T_m = ?$

$T_p = 36\ hr$, $L_r = 1:5$

$H_p = 40\ ft$, $h_p = 5\ ft.$

$Q_p = 3000\ cfs$



Sol.:

$\because \frac{H_m}{H_p} = H_r = L_r$

$\therefore \frac{H_m}{40} = \frac{1}{5} \Longrightarrow H_m = 8\ ft$ #

$\because \frac{h_m}{h_p} = h_r = L_r$

$\frac{h_m}{5} = \frac{1}{5} \Longrightarrow h_m = 1.0\ ft$ #

$$\because \frac{Q_m}{Q_p} = Q_r = \frac{L_r^3}{T_r} = \frac{L_r^3}{L^{1/2}} = L_r^{2.5}$$

$$\therefore \frac{Q_m}{3000} = \left(\frac{1}{5}\right)^{2.5} \Rightarrow Q_m = 53.7 \text{ cfs} \ \#$$

$$\because \frac{T_m}{T_p} = T_r = L_r^{1/2}$$

$$\therefore \frac{T_m}{36} = \left(\frac{1}{5}\right)^{1/2} \Rightarrow T_m = 16 \text{ hr} \ \#$$

A 6 ft uniform flow occurs in a trapezoidal open channel of bed width 10 ft, assuming side slope of 3:2 , n=0.030 , and S = 0.009, what flow rate bottom slope, Manning (n) will be required to model this channel in a laboratory flume of bed width 1.0 ft, assuming no geometric distortion

Given:

$b_p = 10 \text{ ft.}$, $Z_p = 3:2$, $b_m = 1.0$

$n_p = 0.030$, $S_p = 0.009$

Req.: $Q_m = ?$, $n_m = ?$

Sol.:

$$\because \frac{b_m}{b_p} = b_r = \frac{1.0}{10} = L_r$$

$$\because Q = \frac{1}{n} \cdot \frac{A^{5/3}}{P^{2/3}} \cdot S^{1/2}$$

$$A = (10 + 1.5 \times 6) \times 6 = 114$$

$$P = 10 + 2 \times 6 \sqrt{1 + 1.5^2} = 31.6$$

$$\therefore Q_p = \frac{1}{0.03} \times \frac{(114)^{5/3}}{(31.6)^{2/3}} \times (0.009)^{1/2}$$

$$Q_p = 847.9 \text{ ft}^3/s$$

$$\because \frac{Q_m}{Q_p} = Q_r = \frac{L_r^3}{T_r} = \frac{L_r^3}{L_r^{1/2}} = L_r^{2.5}$$

$$\therefore \frac{Q_m}{847.9} = \left(\frac{1}{10}\right)^{2.5}$$

$$\therefore Q_m = 2.68 \ ft^3/s \quad \#$$

$\because$ للحصول على dimension لـ n معامل ماننج

$$Q = \frac{1}{n} \cdot \frac{A^{5/3}}{P^{2/3}} \cdot S^{1/2}$$

$$\frac{L^3}{T} = \frac{1}{n} \cdot \frac{L^{5/3}}{L^{2/3}} \times 1$$

$$n = T/L^2$$

$$\because \frac{n_m}{n_p} = n_r = \frac{T_r}{L_r^2} = \frac{L_r^{1/2}}{L_r^2} = L_r^{-1.5}$$

$$\therefore \frac{n_m}{0.03} = \left(\frac{1}{10}\right)^{-1.5}$$

$$n_m = 0.947 \quad \#$$

Using the dimensional analysis prove that Reynolds No. for a flow in a pipe is a function of the density, the average velocity, the pipe diameter, and the dynamic viscosity.

$\because \quad R_n = f(\rho, V, D, \mu)$

No. of variables = 4

No. of Repeated dim = 3

No. of π = 4 − 3 = 1.0

$(F.L^{-4}.T^{2}), (L.T^{-1}), (L), (F.L^{-2}.T)$

$\because \quad \pi = V^{a}.D^{b}.\mu^{c}.\rho$

$F^{0}L^{0}T^{0} = (L.T^{-1})^{a}.(L)^{b}.(F.L^{-2}.T)^{c}.(F.L^{-4}.T^{2})$

$F: 0 = C + 1 \Rightarrow C = -1$

$T: 0 = -a + c + 2 \Rightarrow a = 1$

$L: 0 = a + b - 2C - 4 \Rightarrow b = 1$

$$\pi = \frac{V.D.\rho}{\mu}$$

$\because \rho/\mu = \nu \Rightarrow \pi = \dfrac{V.D}{\nu} = R_n$ #

A Pelton wheel develops 1500 kw, while the discharge 3m3/sec of water at 300 rpm find the corresponding power , discharge , and speed pf 1/9 model , assuming efficiencies of the two turbines to be the same

Given :.

$\because$ $P_p = 1500$ k.w , $Q_p = 3\ m^3/s'$

$N_p = 300$ rpm

for $L_r = 1/9$

$P_m = ?$, $Q_m = ?$, $N_m = ??$

Sol. :.

$$\because \frac{P_m}{P_p} = P_r = \frac{\cancel{\gamma_r}\,.\,H_r\,.\,Q_r}{\eta_r \times 75}$$

$$= L_r^3 \,.\, T_r^{-1} \times L_r \times 1$$

$$\frac{P_m}{P_p} = \frac{L_r^4}{T_r} = \frac{L_r^4}{L_r^2} = L_r^2$$

(R_n) لأن النموذج مبني على

$$\therefore \frac{P_m}{P_p} = L_r^2 = (1/9)^2$$

$$\therefore \frac{P_m}{1500} = (1/9)^2$$

$$P_m = 18.51 \text{ k.w } \#$$

$$\because \frac{Q_m}{Q_p} = Q_r = \frac{L_r^3}{T_r} = \frac{L_r^3}{L_r^2}$$

$$\frac{Q_m}{Q_p} = L_r$$

$$\frac{Q_m}{3.0} = 1/9$$

$$Q_m = 0.33 \ m^3/S \ \#$$

$$\because \frac{N_m}{N_p} = N_r = \frac{T_r^{-1}}{T_r^{-1}} = 1$$

$$\therefore N_m = N_p = 300 \text{ rpm } \#$$

The power (P) required by the pump is a function of discharge (Q) , the head (H), gravitational acceleration (g), viscosity (μ), and the mass density of the fluid (ρ), speed of rotation (N), and the impeller diameter (D), obtain the relevant dimensionless parameters.

$\because \quad P = f(Q, H, g, \mu, \rho, N, D)$

1. No. of variables = 8

2. $(F.L.T^{-1}) = (L^3.T^{-1}), (L), (L.T^{-2})$
$(F.L^{-2}.T), (F.L^{-4}.T), (T^{-1})$
(L)

3. No. of repeated dim = 3

4. No. of $\pi = 8 - 3 = 5$

5.
$$\pi_1 = Q^a . H^b . \mu^c . P$$
$$\pi_2 = Q^a . H^b . \mu^c . g$$
$$\pi_3 = Q^a . H^b . \mu^c . \rho$$
$$\pi_4 = Q^a . H^b . \mu^c . N$$
$$\pi_5 = Q^a . H^b . \mu^c . D$$

$$\because \quad \pi_1 = Q^a . H^b . \mu^c . \rho$$

$$F^0 . L^0 . T^0 = (L^3 . T^{-1})^a . (L)^b . (F . L^{-2} . T)^c (F . L . T^{-1})$$

$F: \quad 0 = c + 1 \qquad \Rightarrow c = -1$

$T: \quad 0 = -a + c - 1 \qquad \Rightarrow a = -2$

$L: \quad 0 = 3a + b - 2c + 1$

$\quad 0 = -6 + b + 2 + 1 \qquad \Rightarrow b = 4$

$$\pi_1 = \frac{H^4 . \rho}{Q^2 . \mu} \quad \#$$

$$\pi_2 = Q^a . H^b . \mu^c . g$$

$$F^0 . L^0 . T^0 = (L^3 . T^{-1})^a . (L)^b . (F . L^{-2} T)^c (L . T^{-2})$$

$F^0: \quad 0 = c$

$T: \quad 0 = -a + c - 2 \qquad a = -2$

$L: \quad 0 = 3a + b - 2c + 1 \qquad b = -1/3$

$\quad 3a = -b + 2c + 1$

$\quad = -2 + 0 + 1$

$$\pi_2 = \frac{g}{Q^2 . H^{1/3}} \quad \#$$

$$\pi_3 = Q^a . H^b . \mu^c . \rho$$

$$F^0.L^0.T^0 = (L^3.T^{-1})^a . (L)^b . (F.L^{-2}.T)^c . (F.L^{-4}.T)$$

$F: 0 = c + 1 \Rightarrow c = -1$

$T: 0 = -a + c + 1 \Rightarrow a = 0$

$L: 0 = \underbrace{\cancel{3a}}_{0} + b \underbrace{\cancel{-2c}}_{+2} - 4 \Rightarrow b = 2$

$$\pi_3 = \frac{H^2 . \rho}{\mu} \quad \#$$

$$\pi_4 = Q^a . H^b . \mu^c . N$$

$$F^0.L^0.T^0 = (L^3.T^{-1})^a . (L)^b . (F.L^{-2}.T)^c (T^{-1})$$

$F: 0 = c \Rightarrow c = 0$

$T: 0 = -a + c - 1 \Rightarrow a = -1$

$L: 0 = 3a + b \underbrace{\cancel{-2c}}_{0} \Rightarrow b = -3$

$$\pi_4 = \frac{N}{Q * H^3} \quad \#$$

$$\pi_5 = Q^a . H^b . \mu^c . D$$

$$F^0.L^0.T^0 = (L^3.T^{-1})^a . (L)^b . (F.L^{-2}.T)^c . (L)$$

$F: 0 = c \qquad \Rightarrow c = 0$

$T: \ 0 = -a + c \qquad \Rightarrow a = 0$

$L: \ 0 = \underset{0}{\cancel{3a}} + b \underset{0}{\cancel{-2c}} + 1 \Rightarrow b = -1$

$$\Pi_5 = \frac{D}{H}$$

$$\therefore \quad \frac{H^4 \cdot P}{Q^2 \cdot \mu} = f\left(\frac{D}{H}, \frac{g}{Q^2 \cdot H^{1/3}}, \frac{H^2 \cdot \rho}{\mu}, \frac{N}{Q \cdot H^3}\right)$$

#

A trapezoidal canal of bed slope 0.001 , side slope 3:2, and a bed width 3.0 m , carries a discharge of 15.00 m3/sec, assuming that the Manning coef. (1/n =66.67)
It is required to :
(i) The corresponding value of Chezy coeff, (ii) The normal depth
(iii) The critical depth, (iv) The shaer velocity
(v) The type of the flow and its regimes, (vi) The critical slope of the canal
(vii)The average shear stress and draw its distribution on the boundary. If the angle of repose = 30 check stability of the section, and suggest a solution to keep the section stable if it is not

Given :

- $S = 0.001$, $Z = 3/2 = 1.5$
- $b = 3.0\,m$, $Q = 15\ m^3/s$
- $1/n = 66.67$

Sol. :

(i) $\because\ C = \frac{1}{n} R^{1/6}$

$\because\ A = (3 + 1.5 \times 2.25) \times 2.25 = 14.34$

$P = 3 + 3.6 \times 2.25 = 11.10$

$R = 14.34 / 11.10 = 1.30$

$C = 66.67 \times 1.30 \simeq 86.70$ #

(ii) $\because Q = \frac{1}{n} \cdot \frac{A^{5/3}}{P^{2/3}} \cdot S^{1/2}$

$A = (3 + 1.5\, y)\, y$

$P = 3.0 + 2y\sqrt{1 + 1.5^2} = 3.0 + 3.6y$

$\therefore \quad 15 = 66.67 \times \frac{[(3+1.5y)y]^{5/3}}{[3 + 3.60y]^{2/3}} \times (0.001)^{1/2}$

$7.11 = \frac{[(3+1.5y)y]^{5/3}}{[3 + 3.60y]^{2/3}}$

y	1.0	2.0	3.0	2.50	2.3	
R.H.S	3.5	6.2	13.0	9.30	7.94	

$y_n \simeq 2.25\,m$ #

(iii) $\because \frac{Q^2}{g} = \frac{A^3}{T}$

$A = [(3 + 1.5y)y]^3$

$T = 3 + 2 \times 1.5y = 3 + 3y$

$$1.52 \because \frac{15}{9.81} = \frac{[(3+1.5y_c)y_c]^3}{[3+3y_c]}$$

y_c	1.0	0.5			
R.H.S	15.2	1.46			

$y_c \simeq 0.53\,m$ #

(iv) $U^* = \sqrt{g \cdot R \cdot S}$

$= \sqrt{9.81 \times 1.30 \times 0.001}$

$= 0.113\ m/s$ #

(v) $\because Q = A \times V \Rightarrow \therefore V = Q/A$

$\therefore V = \frac{15}{14.34} = 1.05\ m/s$

$\because F_n = \frac{V}{\sqrt{g \cdot y}} = \frac{1.05}{\sqrt{9.81 \times 2.25}}$

$= 0.223 < 1$

sub critical

$$\because \quad R_n = \frac{V \cdot y}{\nu} = \frac{1.05 \times 2.25}{1 \times 10^{-4}} > 2000$$

Turbulent

Regimes of flow #

Turbulent - subcritical flow

(vi)

$$\because \quad Q = \frac{1}{n} \cdot \frac{A^{5/3}}{P^{2/3}} \cdot S^{1/2}$$

$$A_c = (3.0 + 1.5 \times 0.53) \times 0.53 = 2.01$$

$$P_c = 3 + 3.6 \times 0.53 = 4.91$$

$$\therefore \quad 15 = 66.67 \times \frac{(2.01)^{5/3}}{(4.91)^{2/3}} \times S_c^{1/2}$$

$$S_c = 0.0412 \quad \#$$

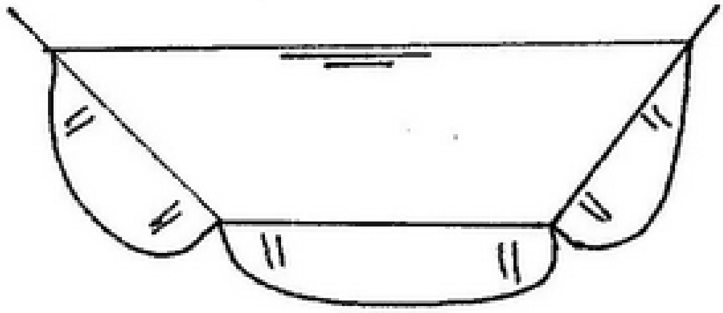
(vii)

$$\tau_o = \gamma \cdot y \cdot S$$

$$= 9810 \times 2.25 \times 0.001$$

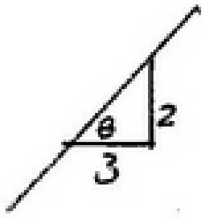
$$= 22.10 \quad N/m^2 \quad \#$$

$$OR = 0.022 \quad Kg/m^2 \quad \#$$



$\because \quad \phi = 30^\circ$

$\theta = \tan^{-1}(2/3) = 33.70$



$\because \quad \theta > \phi$ (unstable):

ولكي يكون القطاع متزن يجب عمل تبطين للقطاع

أو تقليل زاوية ميل الجانبين للقطاع .

A trapezoidal canal with side slope 2:1 carry 17 m3/sec at a bottom slope of 0.001 under a uniform flow conditions, if the canal is to be lined with a galvanized iron having n=0.011, calculate the minimum square meter of the sheet required for lining 100 m length.

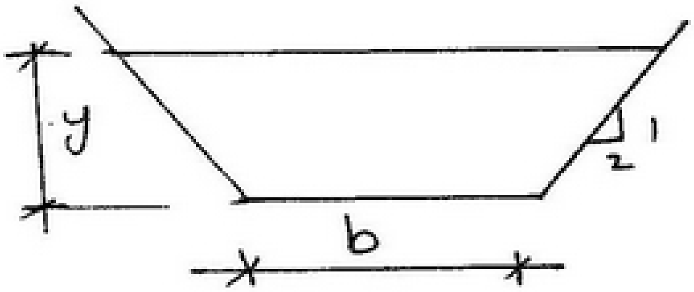
Given:

$\because$ $Z = 2:1$, $Q = 17\ m^3/s$

$S = 0.001$, $n = 0.011$

Sol.:

for minimum lining the section must be B.H.S



$$R = \frac{y}{2}$$

$$\because\ A = (b + 2y)\,y \Rightarrow A = 4.47y^2$$

$$P = b + 2y\sqrt{1+2^2} = b + 4.47y$$

$$\therefore \frac{\cancel{y}}{2} = \frac{(b+2y)\cancel{y}}{b+4.47y}$$

$$\therefore b + 4.47y = 2b + 2y$$

$\therefore \quad b = 2.47y$

$\therefore \quad A = 4.47y^2$

$P = 2.47y + 4.47y = 6.94y$

$\because \quad Q = \frac{1}{n} \cdot \frac{A^{5/3}}{P^{2/3}} \cdot S^{1/2}$

$17 = \frac{1}{0.011} \times \frac{(4.47y^2)^{5/3}}{(6.94y)^{2/3}} \times (0.001)^{1/2}$

$\therefore \quad 1.773 = y^{8/3}$

$y = 1.24\,m$

$b = 3.10\,m$

quantity of lining $= P \times 100$

$= 6.94 \times 1.24 \times 100$

$= 860.60 \quad m^2$

محمد مجدي

A trapezoidal canal having side slope angle of 30 carries a discharge of 10 m3/sec with a depth of flow 1.50 m and a bottom width of 3.0 m under a uniform flow conditions, if the bed slope 0.0009 compute,

(i) The average shear stress in N/m2 on the boundary

(ii)Manning (n) value , (iii) Chezy roughness coefficient, (iv) Darcy friction factor and (v) check validity of the expressions ($n=R^{1/6} / C$), ($C=(f/8g)^{0.5} * R^{1/6}$)

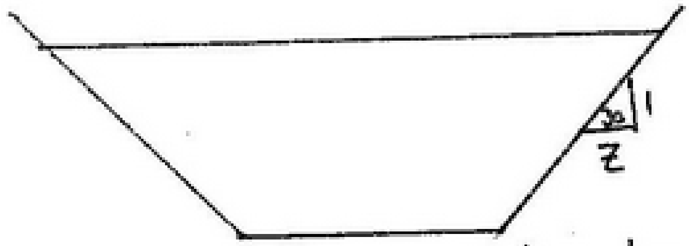
Given.

$Q = 10\ m^3/S$

$y = 1.50\ m$

$b = 3.0\ m$

$S = 0.0009$



$\frac{1}{Z} = \tan 30$

$Z = 1.73$

Sol.:

(i) $\tau_o = \gamma \cdot y \cdot S = 9810 \times 1.5 \times 0.009$

$= 132.44\ N/m^2$ #

(ii) $\because Q = \frac{1}{n} \cdot \frac{A^{5/3}}{P^{2/3}} \cdot S^{1/2}$

$A = (3 + 1.73 \times 1.5) \times 1.5 = 8.40$

$P = 3 + 2 \times 1.5 \times \sqrt{1 + 1.73^2} = 9.0$

$$\therefore \quad 10 = \frac{1}{n} \times \frac{(8.4)^{5/3}}{(9.0)^{2/3}} \times (0.0009)^{1/2}$$

$$n = 0.024 \quad \#$$

(iii) $\therefore \quad C = \frac{1}{n} \cdot R^{1/6}$

$$R = \frac{A}{P} = \frac{8.4}{9} = 0.933$$

$$C = \frac{1}{0.024} \times (0.933)^{1/6}$$

$$C = 41.20 \quad \#$$

(iv) $\therefore \quad C = \sqrt{\frac{8 \cdot g}{f}}$

$$\therefore f = \frac{8 \cdot g}{C^2}$$

$$\therefore f = \frac{8 \times 9.81}{(41.2)^2} = 0.0462 \quad \#$$

A 3.0 m wide rectangular channel carries 2.40 cubic meters per second discharge at a depth of 0.70 m. Do the following

a- Determine the specific energy

b- Determine the critical depth

c- Is the flow is subcritical or supercritical

d- Determine the depth alternate to 0.70 m

e- If the Manning n is 0.015 determine the critical slope

Given:

$$b = 3.0\,m, \quad Q = 2.40\ m^3/s$$

$$y = 0.70\,m$$

Sol.:

(a)

$$\because E = y + \frac{V^2}{2g}$$

$$V = \frac{Q}{A} = \frac{2.4}{(3 \times 0.7)} = 1.14\ m/s$$

$$E = 0.7 + \frac{1.14^2}{2 \times 9.81} = 0.77\,m \quad \#$$

(b)

$$\because y_c = \sqrt[3]{q^2/g}$$

$$q = \frac{Q}{b} = \frac{2.4}{3} = 0.8\ m^3/s/m'$$

$$y_c = \sqrt[3]{\frac{0.8^2}{9.81}} = 0.4\ m \quad \#$$

(c) $\because y > y_c$ subcritical #

(d)

$$\because E = y + \frac{V^2}{2g}$$

$$\therefore E = y + \frac{Q^2}{2gA^2}$$

$$0.77 = y + \frac{(2.4)^2}{2 \times 9.81 \times (3 \times y)^2}$$

$$0.77 = y + \frac{0.032}{y^2}$$

y	0.5	0.45	0.6	0.3	0.25
R.H.S	0.63	0.608	0.69	0.66	0.76

$y \simeq 0.25\ m$ #

(e)

$$\because Q = \frac{1}{n} \cdot \frac{A^{5/3}}{P^{2/3}} \cdot S^{1/2}$$

$$\because A_c = (3 * y_c)$$

$$P = 3 + 2y_c$$

$$\therefore 2.4 = \frac{1}{0.015} \times \frac{(3y_c)^{5/3}}{(3+2y_c)^{2/3}} \times S_c^{1/2}$$

$\because \quad y_c = 0.4\ m$

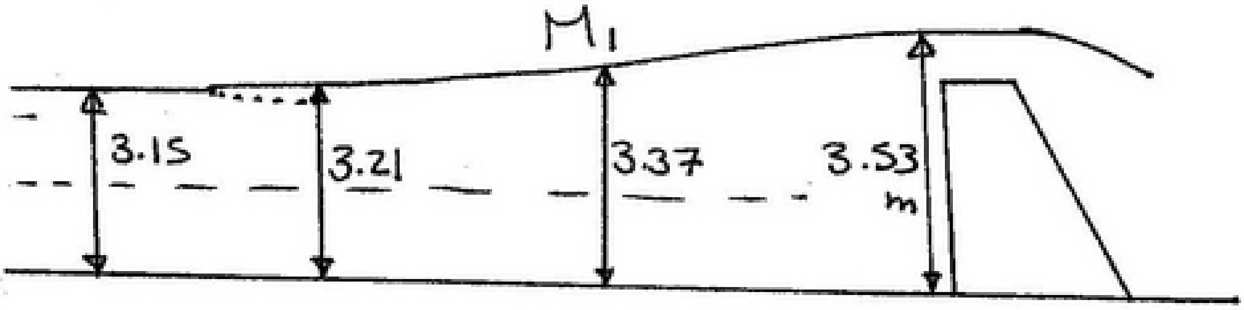
$$\therefore \quad 2.4 = \frac{1}{0.015} \times \frac{(3 \times 0.4)^{5/3}}{(3 + 2 \times 0.4)^{2/3}} \times S_c^{1/2}$$

$S_c = \qquad \#$

A trapezoidal canal having b=6.10 m, z=2, So=0.0016, 1/n = 40, carries a discharge of 11.33 m3/sec, compute the length of the G.V.F profile created by a spillway if the depth just upstream the weir i13.53 m assume that the profile begins at a depth that is greater than the normal depth by 2%, and use an average correction factor of 1.10 (use three steps only), it is essential to specify the type of the profile by numbers and litters.

Given: $b = 6.10\ m, \quad Z = 2, \quad S_o = 0.0016$

$1/n = 40, \quad Q = 11.33\ m^3/s$



$$\because \frac{Q^2}{g} = \frac{A^3}{T}$$

$$A = (b + Zy_c)\,y_c = (6.10 + 2y_c)\,y_c$$

$$T = b + 2Zy_c = 6.10 + 4y_c$$

$$\therefore \frac{(11.33)^2}{9.81} = \frac{\left[(6.10 + 2y_c)\,y_c\right]^3}{(6.10 + 4y_c)}$$

$$13.10 = \frac{((6.10+2y_c)y_c)^3}{(6.10+4y_c)}$$

y_c	1.0	0.5	0.7	0.65
R.H.S	52.6	5.33	16.3	12.80

$y_c \simeq$

$$\therefore \quad Q = \frac{1}{n} \cdot \frac{A^{5/3}}{P^{2/3}} \cdot S^{1/2}$$

$$A = (6.10 + 2y)y$$

$$P = 6.10 + 2 \times y \times \sqrt{1+z^2} = 6.10 + 4.47y$$

$$\therefore 11.33 = 40 \times \frac{[(6.10+2y)y]^{5/3}}{[6.10+4.47y]^{2/3}} \times (0.0016)^{1/2}$$

$$22.40 = \frac{[(6.10+2y)y]^{5/3}}{[6.10+4.47y]^{2/3}}$$

y	1.0	2	3	3.2
R.H.S	3.10	9.96	20.4	22.9

$y \simeq 3.15$ m

$\because \quad y > y_c \quad (\text{Mild})$

$S_o < S_c$

يبدأ المنحنى (M_1) عند عمق أكبر من العمق الطبيعي بمقدار ١٠٪ وبذلك تكون بداية المنحنى عند عمق (3.21 m)

$$\because \quad \Delta x = \frac{\Delta E}{\Delta S}$$

$$\Delta S = S_o - S_{E\,av.}$$

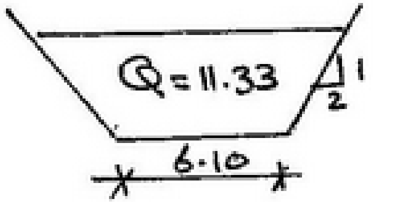
$$S_E = \frac{n^2 \cdot V^2}{R^{4/3}}$$

$$E = y + \frac{1.15\, V^2}{2g}$$

ملحوظة

* ١.١٥ معامل تصحيح للسرعة تم ذكره في المسألة إذا لم يذكر يؤخذ (١.٠٠)

* أقل عدد من خطوات الحل بالجدول ٣ خطوات



$A = (b + zy)y$

$E = y + \frac{1.1 v^2}{2g}$

$P = b + 4.47y$

$S_E = \frac{n^2 \cdot v^2}{R^{4/3}}$

$n = 0.025$

$S_o = 0.0016$

sec.	y	A	v	E	ΔE	P	R	S_E	$S_{E av.}$	ΔS ($S_o - S_{E av.}$)	ΔX
1	3.21	40.2	0.30	3.22		20.45	1.97	2.27×10^{-5}			
					0.16				1.95×10^{-5}	1.58×10^{-3}	10126.6
2	3.37	43.3	0.26	3.38		21.2	2.04	1.63×10^{-5}			
					0.16				1.475×10^{-5}	1.58×10^{-3}	10126.6
3	3.53	46.5	0.24	3.54		21.9	2.12	1.32×10^{-5}			
											20253.2 m

ch* $\boxed{\text{Basic of fluid flow}}$

* forces affecting flow in open channel:

1. inertia force:

(force) F_i = mass x acceleration $= \rho \cdot \forall \cdot a$

(stress) $f_i = F_i$ / area $= \rho \cdot V^2$

2. viscous force:

(force) $F_\tau = A \times \tau = A \cdot \mu \cdot \frac{v}{y}$

(stress) $f_\tau = \mu \cdot \frac{v}{y}$

3. Gravity force

(force) F_g = mass x $g = \rho \cdot \forall \cdot g$

(stress) $f_g = \rho \cdot g \cdot L$

4. surface tension force

(force) $F_\delta = \delta \cdot L$

(stress) $f_\delta = \delta \cdot L / A = \delta / L$

5. elastic force

(force) $F_E = E \times A$

(stress) $f_E = E$

★ flow dimensionless parameters:

1. Reynold No:

$$R_n = \mathbb{R} = \frac{f_i}{f_\tau} = \frac{\rho \cdot V^2}{\mu \cdot \frac{V}{y}} = \frac{V \cdot y}{\upsilon}$$

2. Froude No.

$$F_n = \mathbb{F} = \left(\frac{f_i}{f_g}\right)^{1/2} = \left(\frac{\rho \cdot V^2}{\rho \cdot g \cdot L}\right)^{1/2} = \frac{V}{\sqrt{g \cdot y}}$$

3. Cauchy No,

$$D = \frac{f_i}{f_E} = \frac{\rho \cdot V^2}{E}$$

4. Mach No,

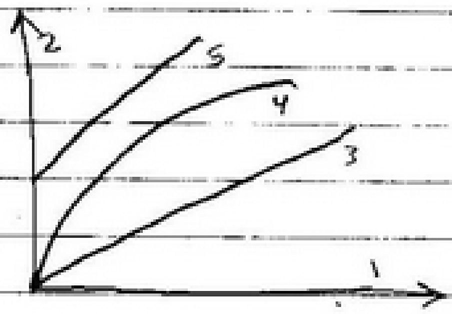
$$M = \left(\frac{f_i}{f_E}\right)^{1/2} = \frac{V}{\sqrt{E/\rho}}$$

5. weber No,

$$W = \left(\frac{f_i}{f_\sigma}\right)^{1/2} = \left(\frac{\rho \cdot V^2}{\sigma / L}\right)^{1/2} = \frac{V}{\sqrt{\frac{\sigma}{\rho \cdot y}}}$$

★ Types of fluid

1- Ideal fluid
2- elastic solid
3- Newtonian fluid
4- Non-Newtonian fluid
5- Ideal plastic



ch 2 $\boxed{\text{Classification of open channel}}$

★ classification of open channel:

1. according to nature
   - natural canals
   - artificial canals
2. according to nature of boundary
   - Rigid canals
   - alluvial canals
3. according to cross section and slope
   - prismatic canals
   - non-prismatic canals

★ classification of flow

1. according to Time:
   - steady flow
   - non-steady flow
2. according to distance
   - uniform flow
   - non-uniform flow
3. according to Reynold No,
   - Laminar flow $R_n < 500$
   - Transition flow $500 < R_n < 2000$
   - Turbulent flow $R_n > 2000$
4. according to froude No,
   - sub critical flow $F_n < 1$
   - super critical flow $F_n > 1$
   - critical flow $F_n = 1$
5. according to variation of depth with distance:
   - gradually varied flow (G.V.F)
   - Rapidly varied flow (R.V.F)

ch.3: $\boxed{\text{Geometric properties of open channel}}$

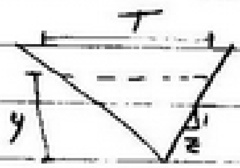
★ <u>Rectangular section:</u>

$A = b \cdot y$

$P = b + 2y$

<u>B.H.S:</u> $b = 2y$ $\quad R = y/2$

★ <u>Triangular section:</u>



$A = \frac{1}{2} \cdot T \cdot y$

$P = 2\sqrt{\left(\frac{T}{2}\right)^2 + y^2}$

$Z = A\sqrt{y}$

<u>B.H.S:</u> $Z = 1$ $\quad R = \frac{y}{2\sqrt{2}}$ $\quad T = 2y$ $\quad \theta = 90$ $\quad Z = 1:1$

★ <u>Tropizoidal section:</u>

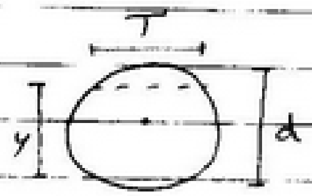
$A = (b + zy)y$

$P = b + 2y\sqrt{1 + z^2}$

<u>B.H.S:</u> Z const $\quad R = y/2$

y const $\quad Z = 1/\sqrt{3}$

★ <u>Circular section:</u>



<u>B.H.S:</u> $\theta_r = \pi$ $\quad \theta = 180$

$R = d/4$

ch 4 $\boxed{\text{Discharge equations in open channel}}$

$\boxed{\text{Chezy}}$

$$V = C \cdot R^{1/2} \cdot S^{1/2}$$

$$Q = C \cdot \frac{A^{3/2}}{P^{1/2}} \cdot S^{1/2}$$

$\boxed{\text{Kutter}}$

$$C = \frac{41,65 + (0,00281/S) + (1,811/n)}{1 + (41,65 + 0,00281/S) \times \frac{n}{R}} \quad (ft)$$

$$C = \frac{23 + (0,00155/S) + (1/n)}{1 + (23 + 0,00155/S) \times \frac{n}{R}} \quad (m)$$

$$n = 0,009 \longrightarrow 0,033$$

$\boxed{\text{Bazin}}$

$$C = \frac{157,6}{1 + m/\sqrt{R}} \quad (ft) \qquad C = \frac{157,6}{1,81 + m/\sqrt{R}} \quad (m)$$

$$m = 0,11 \longrightarrow 3,17$$

$\boxed{\text{Powell}}$

$$C = -42 \log\left[\frac{C}{4 R_n} - \frac{\varepsilon}{R}\right] \qquad \varepsilon = 0,002 \to 0,1$$

for smooth bed $\varepsilon = 0$

$$C = 42 \log\left[\frac{4 R_n}{C}\right]$$

for rough canals:

$$C = 42 \log\left[\frac{\varepsilon}{R}\right]$$

$\boxed{\text{Mannong}}$ $V = \frac{1}{n} \cdot R^{2/3} \cdot S^{1/2}$ (m)

$n_{eq} = \left(\frac{\Sigma P_i \cdot n_i^{1.5}}{\Sigma P_i}\right)^{2/3}$ $V = \frac{1.486}{n} \cdot R^{2/3} \cdot S^{1/2}$ (ft)

$$Q = \frac{1}{n} \cdot \frac{A^{5/3}}{P^{2/3}} \cdot S^{1/2} \quad (m)$$

$$Q = \frac{1.486}{n} \cdot \frac{A^{5/3}}{P^{2/3}} \cdot S^{1/2} \quad (ft)$$

$\boxed{\text{relation between } C, n}$

$$C = \frac{1}{n} \cdot R^{1/6} \quad (m)$$

$$C = \frac{1.486}{n} R^{1/6} \quad (ft)$$

$\boxed{\text{Pavlovesk}}$ $C = \frac{1}{n} \cdot R^{y}$

$$y = 2.5\sqrt{n} - 0.1 - \left[0.75\sqrt{R} \times (\sqrt{n} - 0.1)\right]$$

$\boxed{\text{Buckly}}$ canals: $y = \frac{(S+8)^2}{650} \times b$ $b \leq 1.62$

$y = 0.1\left(\frac{S}{2} + 4\right) \times \sqrt{b}$ $b > 1.62$

drain: $y = b$ $b \leq 2$

$y = 1.75 \sqrt[3]{b}$ $b > 2$

$\boxed{\text{relation between } C, f}$

$$f = \frac{8 \times g}{C^2}$$

ch 5.

$\boxed{\text{velocity distribution}}$

*** uniform laminar flow:**

$$u = \frac{g \cdot S}{\nu}\left(y y_0 - \frac{y^2}{2}\right)$$

*** uniform turbulent flow:**

$$\frac{u}{u_*} = 5{,}75 \log\left(\frac{9 \cdot y \cdot u_*}{\nu}\right) \qquad \text{smooth bed}$$

$$\frac{u}{u_*} = 5{,}75 \log\left(\frac{30\, y}{K}\right) \qquad \text{Rough bed}$$

$$u_* = \sqrt{g \cdot R \cdot S} = \sqrt{\frac{\tau}{\rho}}$$

K = van Karman const. = 0,4 clear

= 0,2 sediments

ch 6. **Boundary shear in open channel**

* Tractive force distribution:

$$\tau_s = \frac{w}{a} \cos\theta \tan\phi \sqrt{1 - \frac{\tan^2\theta}{\tan^2\phi}}$$

$$\tau_b = \frac{w}{a} \tan\phi$$

θ : زاوية ميل جوانب القناة

ϕ : زاوية الميل الطبيعي للتربة

a : المساحة المعرضة للقص

w : الوزن المؤثر على الجوانب او القاع

* Tractive force ratio:

$$K = \frac{\tau_s}{\tau_b} = \cos\theta \sqrt{1 - \frac{\tan^2\theta}{\tan^2\phi}}$$

* shear stress:

$$\tau_o = \gamma \cdot y \cdot S$$

* special case:

$b = 4y \qquad z = 1.5$

$$\tau_s = 0.75\ \tau_o = 0.75\ \gamma \cdot y \cdot S$$

$$\tau_b = 0.97\ \tau_o = 0.97\ \gamma \cdot y \cdot S$$

$$H_p = H_{st} + \left\{ \frac{8\,fL}{\underset{9.8}{g}\,.\,\pi^2\,D^5} + K_u \right\} Q^2$$

$$H_p = \frac{\gamma \,.\, Q \,.\, H}{75 \times \eta \rightarrow 0.60}$$

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}} \qquad \text{(specific speed)}$$

$$\frac{Q_2}{Q_1} = \frac{N_2}{N_1} \times \frac{D_2}{D_1}$$

$$\frac{H_2}{H_1} = \left[\frac{N_2}{N_1}\right]^2 \times \left[\frac{D_2}{D_1}\right]^2$$

$$\frac{P_2}{P_1} = \left[\frac{N_2}{N_1}\right]^3 \times \left[\frac{D_2}{D_1}\right]^3$$

$$E = y_1 + \frac{v_1^2}{2g}$$

$Q = A \cdot V$

$Q = q \cdot B$

$$E = y + \frac{q^2}{2gy^2}$$

$$g \cdot y_c^3 = q^2 \longrightarrow y_c = \sqrt[3]{q^2/g}$$

$$E_{min} = 1.5\, y_c$$

$$E = y + \frac{Q^2}{2gA^2}$$

$$\frac{Q^2}{g} = \frac{A^3}{T} \qquad E_{min} = y + \frac{y_h}{2}$$

$$F = \frac{1}{2} \gamma \cdot y^2 + \rho \cdot Q \cdot V$$

$Q = A \cdot v$

$q = y \cdot v$

$$F_{min} = 1.5\, y_c^2$$

$$\frac{dy}{dx} = \frac{S_o - S_F}{1 + \frac{d}{dy}\frac{\alpha V^2}{2g}}$$

G.V.F

$$\Delta X = \frac{\Delta E}{\Delta S} = \frac{E_2 - E_1}{S_o - S_E}$$

sec	y	A	V	E	ΔE	P	R	S_E	$S_{E_{av}}$	ΔS	ΔX	ΣΔX

$$S_E = \frac{n^2 \cdot v^2}{R^{4/3}}$$

Faculty of Engineering	First Term final Exam	Date : 30 Jan,2010
Academic year : 3rd		Time : 3 hrs
Specialization : Civil		No. of parts : 1
Course Name : Open Channel Hydraulics		No. of pages : 2
Course Code :		No. of Questions : 4
Department : Dept: W. & Water Str. Eng.	Zagazig University	Full Mark 90

Question No. (1) : [20 Degrees]

Write a mathematical condition for each of the following:

A) Most efficient hydraulic section of trapezoidal open channel

B) Maximum velocity and maximum discharge in pipe open channel

C) Unsteady flow in open channel

D) Uniform flow in open channel

B) Use the momentum equation to drive the following:

$$v = C\sqrt{RS}$$

$$\tau_0 = \gamma RS$$

C) A trapezoidal channel carrying discharge of $40 m^3/sec$. The bed slope is 10 cm/km, side slope is 1:1 and n = 0.025. Design the channel cross-section dimensions for the following two cases:

1) The maximum allowable velocity is 0.50 m./sec.

2) The maximum allowable shear stress is $0.20\ kg/m^3$.

3) The section is of best hydraulic section

If the water kinematic viscosity is $1.0 \times 10^{-6}\ m^2/sec$, define the flow regime passing through this channel for each case?

Question No. (2): [25 Degrees]

A) Prove that $\frac{Q^2}{g} = \frac{A^3}{T}$ for non-rectangular section at critical flow condition

B) Design stable trapezoidal section to carry $Q=20\ m^3/s$, if the channel side slope is 2, longitudinal slope is 12 cm/km. if d_{50}=3.0 mm, n=0.015, $\phi = 30^0$, $\gamma_s = 2.65\ t/m^3$.

C) 4.0 m wide rectangular section carries a discharge of $16\ m^3/s$ at depth of 1.50 m

- What will be the depth over a hump of 0.30 m
- Find the difference in water levels before and after the hump
- What will you do to maintain the water level unchanged
- Draw the relation between the two alternative depths and the hump height

Question No. (3) : [25 Degrees]

A)

What we are mean by each of the followings:

*Two alternative depths and two conjugate depths

*Hydraulically rough and hydraulically smooth

*Celerity

*Incipient motion

*Tractive force ratio

*Conveyance factor

*Control section

*Distorted model and undistorted model

*Gradually and rapidly varied flow

B) Calculate the model velocity for open channel if length scale of 1/10 and prototype velocity is 3m/s.

C) Long trapezoidal channel of 4.0 m width, side slope 2:1 longitudinal bed slope is 0.05carrying discharge of 25 m^3/sec, n= 0.025, at a certain section the channel bed slope changed to 0.00003. determine

a. Sketch the water surface profile

b. Calculate the relative initial water depth, jump efficiency then Calculate the length in which the flow is non-uniform

Question No. (4): [20 Degrees]

A. Drive the dynamic equation for gradually varied flow in terms of shape factor and conveyance factor

B. single pump of constant speed of 1400 r.p.m is used to left water from tank A to tank B. if the pipe performance curve is given as following

Q (m^3/sec)	0	0.20	0.40	0.75	0.95	1.25
Head (m)	13	12.0	11.0	9.0	7.0	3.0
Efficiency (%)	0	55	85	80	70	50

And the operation curve is given as

$H_p = 5.6 + Q^2$

Required to find out

- The shut of head
- The static head
- The discharge passing
- Horsepower
- What is the passing discharge if the pump speed is changed to 1600 r.m.p

C. Neglecting the effect of surface tension and viscosity, prove that the discharge over a spillway can be expressed as: $Q = VD^2 f\{(gD)^{1/2}/V, H/D\}$. In which Q is the discharge, V is the velocity, H is the head, D is the throat depth and g is the gravitational acceleration.